Letter from Alexander Graham Bell to Mabel Hubbard Bell, October 25, 1901

Beinn Bhreagh Victoria County. Cape Breton, N. S October 25, 1901. Dear Mabel: —

Since you left, the kite, or rather the flying machine, has occupied pretty nearly all of my thoughts. I have realized that Prof. Newcomb has done a great service by pointing out the undoubted fact that you cannot increase indefinitely the dimensions of a flying machine upon any given model, because the weight will increase as the cube of the dimensions; whereas the sustaining surfaces increase only as the square of the dimensions. So that the FLYING WEIGHT — that is the ratio of weight to surface — continually increases with the size of your model and large machines, capable of carrying men and engines, &c. would be impracticable because their weights would be too great to be sustained by their surfaces.

I find this is as true of kites as of flying machines

A

B

For example, if you construct two kites (A) and (B) upon the same model — one of double the dimensions of the other in every way, — (B) will weigh 8 times as much as (A), but have only four times the supporting surface, so that the flying weight of (B) — that is the ratio of weight to surface — is twice as 2 great in (B) as in (A).

If you make (B) three times the dimensions of (A) in every respect, then (B) will weigh 27 times as much as (A), and expose only 9 times as much supporting surface, so that its flying weight — or ratio of weight to surface — will be three times as great.

Thus, it is obvious that as you increase the dimensions of your kite, you increase the flying weight (or ratio of weight to surface), so that a limit of size would soon be reached beyond which your kite would not fly. This is undoubtedly the reason why the giant kites I constructed some years ago, on the model of my smaller kites, were unsuccessful, because the flying weight proved to be too great, and it would have taken a hurricane to raise them.

The first realization of the truth of Newcomb's Law, came as a shock, as it seemed to throw doubt upon the practicability of constructing flying machines upon the Heavier than air principle, of a sufficiently large size to carry up men and engines, &c. unless a new principle of support — momentum — was introduced.

In kites — which are stationary on account of being attached to the ground by a string — the question of momentum does not enter as a factor. They have no velocity proper of their own and hence have no momentum. So, Newcomb's law applies in full force to kites, and at first sight it seemed as though it would be impracticable to construct a large kite that would carry up 3 a man. This was a great blow to me, but further consideration of the problem assured me that Newcomb's conclusions were only half true; and the experiments I have made here have demonstrated the fact that although his process of reasoning is right his general conclusion is WRONG; and I now see that he has erred because in his general conclusion he has gone outside of the premises with which he started.

His premise is as follows: —

“Let us make two flying machines exactly alike, only make one on double the scale of the other in all its dimensions”.

From this he draws a first conclusion which is undoubtedly correct: —

“We all know that the volume, and therefore the weight of two similar bodies are proportioned to the cubes of their dimensions. The cube of 2 is 8. Hence the large

machine will have 8 times the weight of the other. But surfaces are as the squares of the dimensions. The square of 2 is 4. The heavier machine will therefore expose only four times the wing surface to the air, and so will have a distinct disadvantage in the ratio of efficiency to weight."

His general conclusion is: —

"That the construction of an aerial vehicle, which could carry even a single man from place to place, at pleasure, requires the discovery of some new metal or some new force."

He thus draws a general conclusion from a restricted premise. His premise is that the large and the small machine shall be "exactly alike", only differing in the scale of their dimensions. His conclusion is that a large machine — whether exactly like the smaller one or not — cannot be made to carry 4 up a man, &c. A sweeping conclusion not justified by his premises, and a conclusion which, I venture to believe, the experiments made here since you left have demonstrated to be FALSE.

The experiments here show that his first conclusion is correct, for, if you make two kites "exactly alike, only making one on double the scale of the other in all its dimensions," the larger kite weighs 8 times as much as the former, but has only 4 times the supporting surface."

But the experiments also show that this is not a general conclusion, but only a special conclusion in a special case, for three of my triangular kites tied together fly as well as when separate, and weigh only three times as much as one kite

The compound kite thus formed has the same length as the original but twice the width. It contains 9 longitudinal sticks on which the cloth is stretched, but in the compound form 3 of those sticks can be omitted, as in the second diagram below so that you have here a compound kite having 3 times the surface 5 but l ess than three times the weight of the original kite — less by the three sticks omitted. The flying weight of the larger kite — that

is the relation of weight to surface — is LESS — not greater — than in the case of the smaller kite, so it will sustain a larger, not a smaller, proportionate load. The triple kite will sustain more than 3 times the load sustained by the smaller kite. This result you will observe, is entirely opposed to Newcomb's conclusion.

In the above case we have only doubled the width of the kite and not its length. If we double the dimensions of the KITE we find that the larger kite can be built up by tying together 6 of the smaller kites so that the larger kite exposes 6 times the surface of the smaller kite and weighs just six times as much. A result entirely opposed to Newcomb's general conclusion.

But, as shown above in the case of the three kites, some of the longitudinal sticks can, with advantage be omitted, in constructing the larger form, so that the compound kite weighs LESS than six times the original kite.

In the above case we have doubled the dimensions of the KITE in all its parts without doubling the dimensions of the material of which the kite is made. The construction of the large kite is equally stong with that of the small kite, and yet 6 Newcomb's law does not apply. The weight of the larger kite is NOT 8 times that of the smaller, nor its surface 4 times. The surface is 6 times that of the smaller, and the weight less than 6 times.

The importance of the cellular construction becomes apparant upon reflection. As we increase the number of component cells the flying weight becomes less and less by the omission of multitudinous longitudinal sticks without weakening the construction. That is:— the weight of the kite proportionally to its surface becomes less as we increase the dimensions of the compound form.

Keeping the length of the kite constant, and building up a compound form by placing triangular cells, side by side as shown, and calling the side of one cell (1), the surface of one of the elemental kites (1), and its weight (1), we find that a compound kite having a side twice that of the other has a surface three times that of the first, and a weight three

times 7 that of the first minus three longitudinal sticks, &c. We will make a table of the results as shown in the diagrams above: —

RELATION OF WEIGHT TO SURFACE.

LENGTH OF SIDE SURFACE WEIGHT OF KITE 1 1 1 2 3 3 — (3 sticks) 3 6 6 — (8 sticks) 4 10 10 — (15 sticks) 5 15 15 — (24 sticks) 6 21 21 — (35 sticks) 7 28 28 — (48 sticks) 8 36 36 — (63 sticks)

The weight of the kite compared to the supporting surface constantly diminishes with increase of size, from which it follows that the additional load that can be carried increases in the same proportion.

I have no time to elaborate further before this mail goes, and so will close now. You can show this letter to Prof. Langley if you like. I think he will appreciate the importance of the cellular construction.

Your loving husband Alec. M r . A. Graham Bell 1331 Conn. Avenue Washington D. C.